Predicting Performance and Designing Systems

Small Wind Systems Tutorial

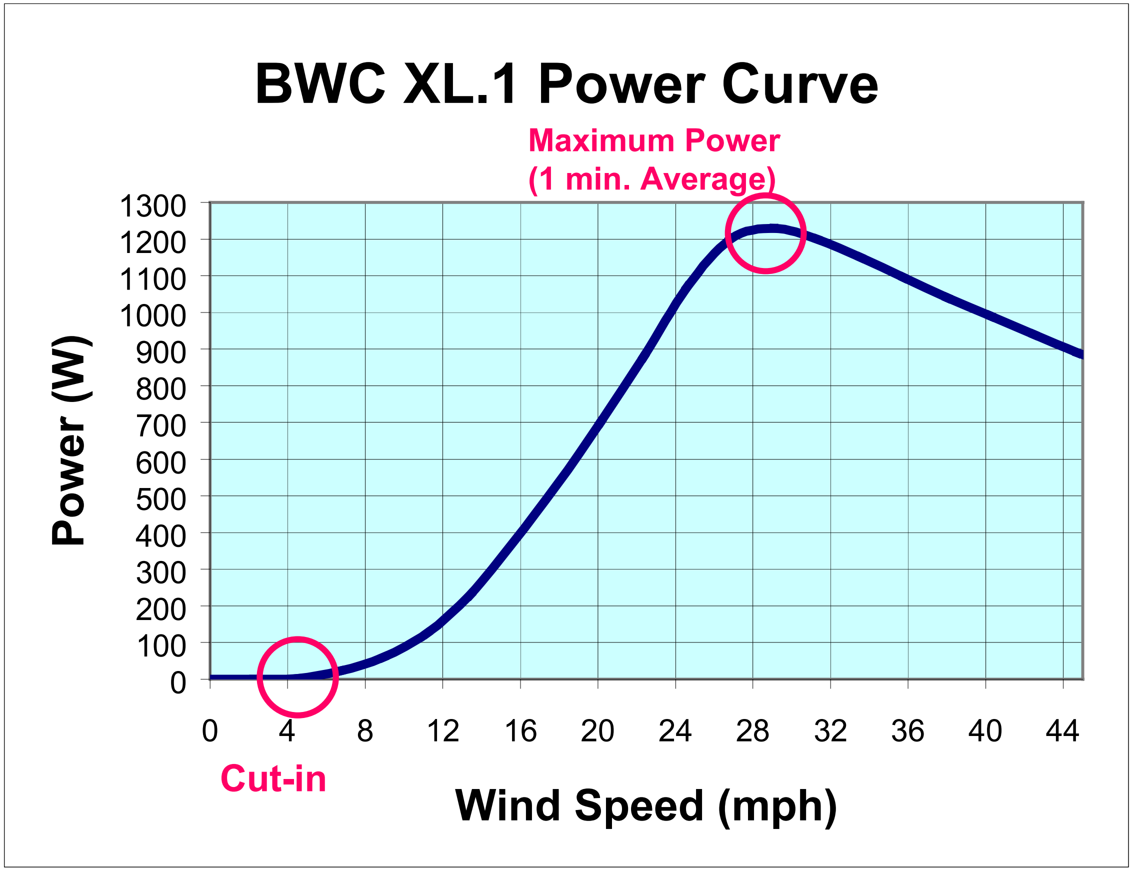
Village Power Conference Workshop

BERGEY WINDPOWER

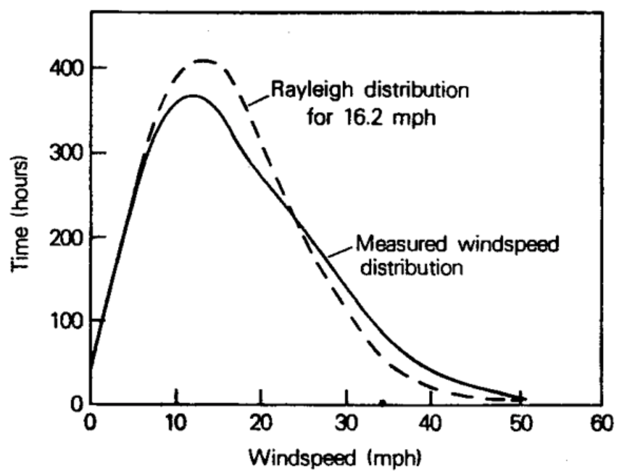
Part 6

Performance Specifications

Based on averaged field test data

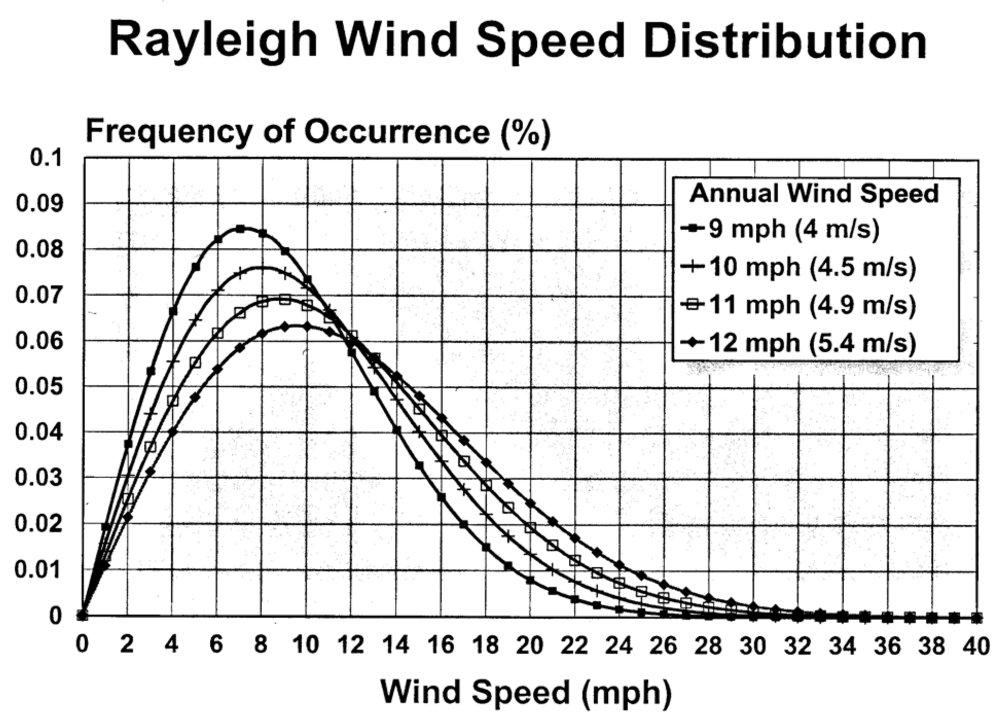


Modeling Wind Speed Distributions



Based on Monthly or Annual Average Wind Speed

Frequency Distribution Defined by One Number (average wind speed)



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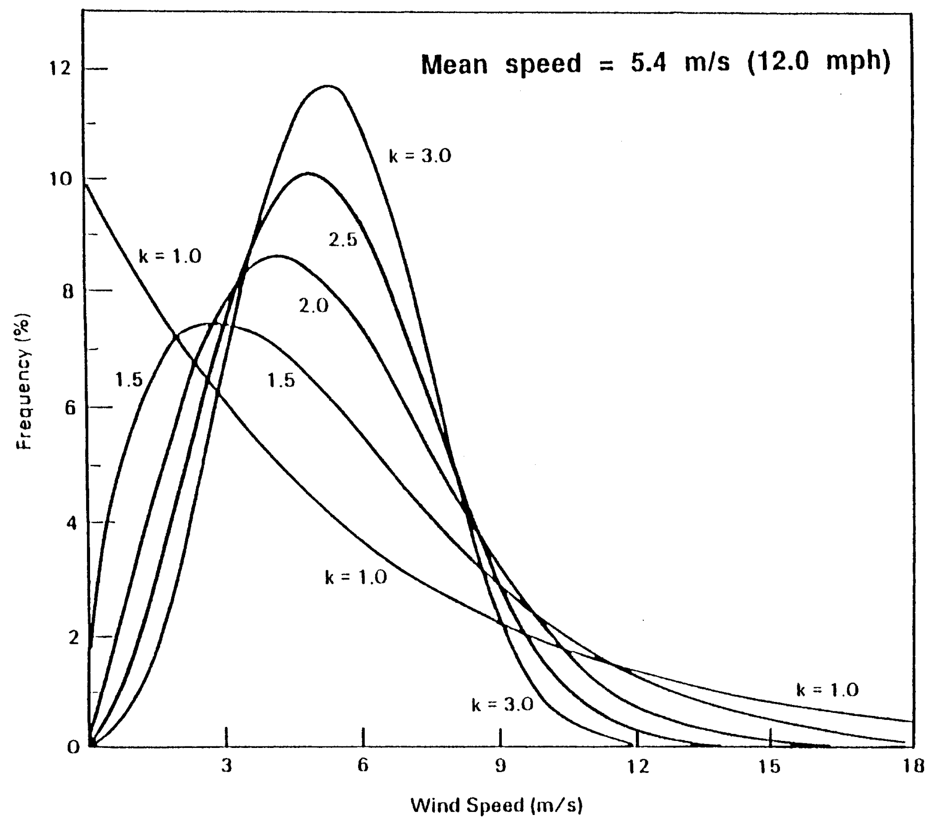
Weibull "K" Shape Factor

- Widens / Narrows Speed Distribution
- Inland: K = 1.5 - 2.5
- Coastal: K = 2.5 - 3.5
- Trade Wind: K = 3 - 4
- Higher K = Less Energy
- K = 2 is a Rayleigh Distribution

Two Parameters (V and K) Define the Wind



Graphic courtesy of AWS Scientific

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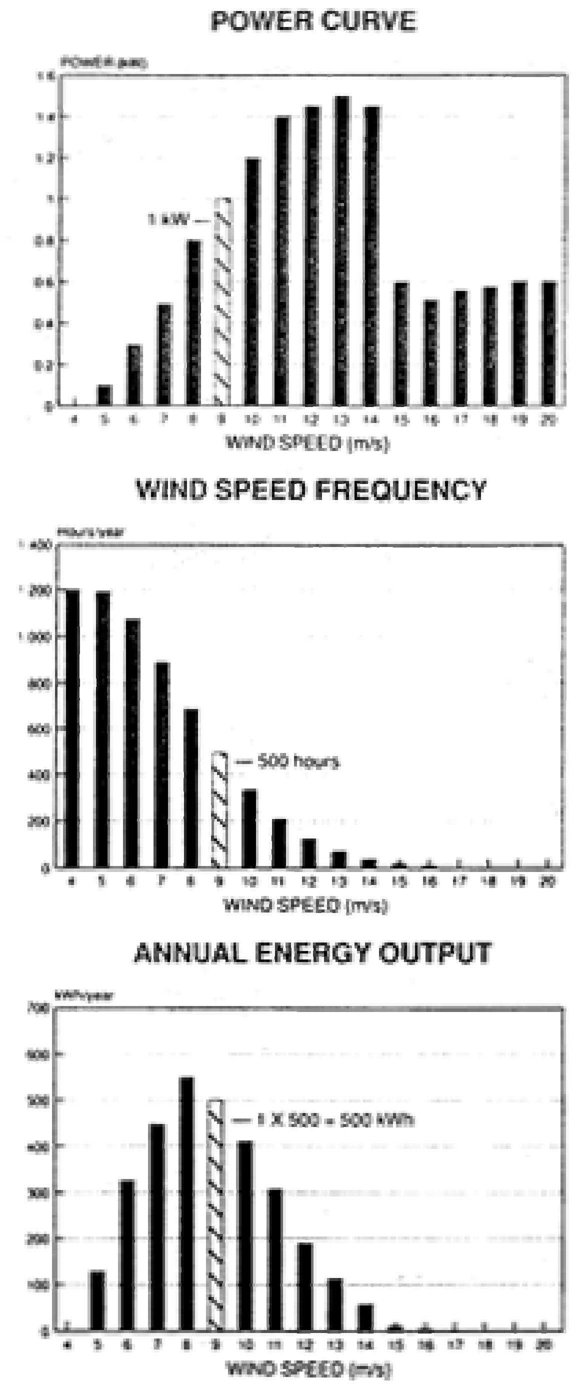
“Bins” Method

- Multiply the Turbine Power Curve by the Wind Speed Frequency Distribution Curve <u>on a Bin by Bin Basis</u>
- Sum the Results from 0 - ~20 m/s = Mean Power Output (MPO), in Watts
- Daily Energy Produced = MPO x 24 Hrs
- Annual Energy Output (AEO) = MPO x 8765 Hrs



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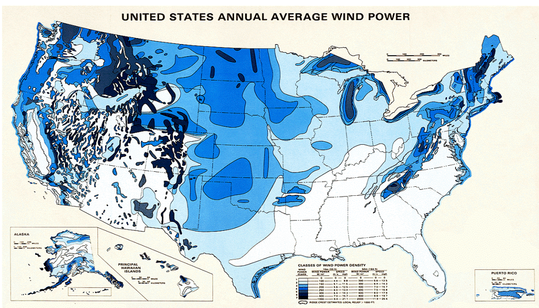
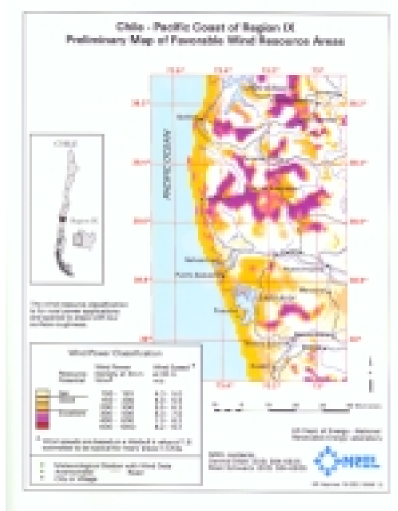
Performance Prediction

Annual average taken from US-DOE Wind Atlas,



or New Generation Map …



and inputted into performance model

WindCad Turbine Performance Model

BWC EXCEL-S, Grid - Intertie

Prepared For:	**SCE Customer**
Site Location:	**Tehachapi, CA**
Data Source:	**U.S. DOE Wind Atlas**
Date:	**11/12/00**

Inputs:

Ave. Wind (m/s) =	5.5
Weibull K =	2
Site Altitude (m) =	50
Wind Shear Exp. =	0.180
Anem. Height (m) =	10
Tower Height (m) =	30
Turbulence Factor =	10.0%

Results:

Hub Average Wind Speed (m/s) =	6.70
Air Density Factor =	0%
Average Output Power (kW) =	2.07
Daily Energy Output (kWh) =	49.8
Annual Energy Output (kWh) =	**18,166**
Monthly Energy Output =	1,514
Percent Operating Time =	80.6%

Weibull Performance Calculations

Wind Speed Bin (m/s)	Power (kW)	Wind Probability (f)	Net kW @ V
1	0.00	3.46%	0.000
2	0.00	6.57%	0.000
3	0.00	9.03%	0.000
4	0.16	10.64%	0.017
5	0.45	11.35%	0.051
6	0.89	11.22%	0.099
7	1.52	10.40%	0.158
8	2.33	9.13%	0.213
9	3.23	7.61%	0.245
10	4.26	6.05%	0.257
11	5.35	4.59%	0.246
12	6.50	3.34%	0.217
13	7.78	2.33%	0.181
14	9.09	1.56%	0.142
15	10.26	1.00%	0.103
16	10.75	0.62%	0.066
17	10.66	0.37%	0.039
18	10.30	0.21%	0.022
19	9.85	0.12%	0.011
20	9.41	0.06%	0.006
1999, BWC	Totals:	99.65%	2.074

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WindCAD

- **Spreadsheet Model for Wind Turbine Performance Prediction**
- **Created for BWC Turbines, but Easily Adapted to any Wind Turbine (modify power curve data)**
- **Simple Inputs**
- **Use with Monthly and Annual Wind Averages … Not for Shorter Periods**

Instructions

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WindCad Turbine Performance Model

BWC XL.1 24VDC Battery Charging Version

MS Excel, V.97 PC

Prepared For:
Site Location:
Data Source:
Date: **11/29/00**

1.1 kW

Inputs:	
Ave. Wind (m/s) =	5.00
Weibull K =	2
Site Altitude (m) =	300
Wind Shear Exp. =	0.200
Anem. Height (m) =	10
Tower Height (m) =	24
Turbulence Factor =	10.0%
Perf. Safety Margin =	5.0%

Results:	
Hub Average Wind Speed (m/s) =	5.96
Air Density Factor =	-3%
Average Output Power (W) =	0.27
Daily Energy Output (kWh) =	**6.3**
Annual Energy Output (kWh) =	2,285
Monthly Energy Output =	190
Percent Operating Time =	76.1%

Weibull Performance Calculations

Wind Speed Bin (m/s)	Power (kW)	Wind Probability (f)	Net kW @ V
1	0.00	4.37%	0.00
2	0.00	8.17%	0.00
3	0.02	10.96%	0.00
4	0.05	12.49%	0.01
5	0.10	12.78%	0.01
6	0.17	11.99%	0.02
7	0.28	10.47%	0.03
8	0.44	8.56%	0.04
9	0.60	6.59%	0.04
10	0.76	4.79%	0.04
11	0.92	3.30%	0.03
12	1.10	2.15%	0.02
13	1.19	1.33%	0.02
14	1.21	0.79%	0.01
15	1.20	0.44%	0.01
16	1.17	0.24%	0.00
17	1.13	0.12%	0.00
18	1.09	0.06%	0.00
19	1.03	0.03%	0.00
20	0.96	0.01%	0.00
2000, Bergey Windpower Co	Totals:	99.62%	0.27

Weibull Calculations: Wind speed probability is calculated as a Weibull curve defined by the average wind speed and a shape factor, K. To facilitate piece-wise integration, the wind speed range is broken down into "bins" of 1 m/s in width (Column 1). For each wind speed bin, instantaneous wind turbine power (W, Column 2)) is multiplied by the Weibull wind speed probability (f, Column 3). This cross product (Net W, Column 4) is the contribution to average turbine power output contributed by wind speeds in that bin. The sum of these contributions is the average power output of the turbine on a continuous, 24 hour, basis. Best results are achieved using annual or monthly average wind speeds. Use of daily or hourly average speeds is not

Instructions:
Inputs: Use annual or monthly **Average Wind** speeds. If **Weibull K** is not known, use K = 2 for inland sites, use 3 for coastal sites, and use 4 for island sites and trade wind regimes. **Site Altitude** is meters above sea level. **Wind Shear Exponent** is best assumed as "1/7" or 0.143. For rough terrain or high turbulence use 0.167. For very smooth terrain or open water use 0.110. **Anemometer Height** is for the data used for the **Average Wind** speed. If unknown, use 10 meters. **Tower Height** is the nominal height, eg.: 24 meters. **Turbulence Factor** is a derating for turbulence, product variability, and other performance influencing factors. Use 0.1 (10%) - 0.15 (15%) is most cases. **Performance Safety Margin** is a derating that accounts for unuseable energy (eg.: batteries full) and adds a margin of safety in satisfying the load requirements. Use 0.05 (5%) for remote homes and village power sites with back-up power. Use 0.15 (15%) - 0.25 (25%) for telecommunication applications with back-up power. Use 0.2 (20%) - 0.4 (40%) for high-priority loads at sites without back-up power (should have solar component).
Results: **Hub Average Wind Speed** is corrected for wind shear and used to calculate the Weibull wind speed probability. **Air Density Factor** is the reduction from sea level performance. **Average Power Output** is the average 24-hour power produced, without the performance safety margin adjustment. **Daily Energy Output** includes all deratings and is the primary performance parameter. **Annual** and **Monthly Energy Outputs** are calculated for the Daily value. **Percent Operating Time** is the time the turbine should be producing some power.
Limitations: This model uses a mathmatical idealization of the wind speed probability. The validity of this assumption is reduced as the time period under consideration (ie, the wind speed averaging period) is reduced. This model is best used with annual or monthly average wind speeds. Use of this model with daily or hourly average wind speed data is not recommended because the wind will not follow a Weibull distribution over short periods. Consult Bergey Windpower Co. for special needs. **Actual Performance May Vary !**

WindCAD

Inputs:

Ave. Wind (m/s) =	5.00
Weibull K =	2
Site Altitude (m) =	300
Wind Shear Exp. =	0.200
Anem. Height (m) =	10
Tower Height (m) =	24
Turbulence Factor =	10.0%
Perf. Safety Margin =	5.0%

Results:

Hub Average Wind Speed (m/s) =	5.96
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Average Output Power (W) =	0.27
Daily Energy Output (kWh) =	**6.3**
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4	0.05	12.49%	0.01
5	0.10	12.78%	0.01
6	0.17	11.99%	0.02
7	0.28	10.47%	0.03
8	0.44	8.56%	0.04
9	0.60	6.59%	0.04
10	0.76	4.79%	0.04
11	0.92	3.30%	0.03
12	1.10	2.15%	0.02
13	1.19	1.33%	0.02
14	1.21	0.79%	0.01
15	1.20	0.44%	0.01
16	1.17	0.24%	0.00
17	1.13	0.12%	0.00
18	1.09	0.06%	0.00
19	1.03	0.03%	0.00
20	0.96	0.01%	0.00
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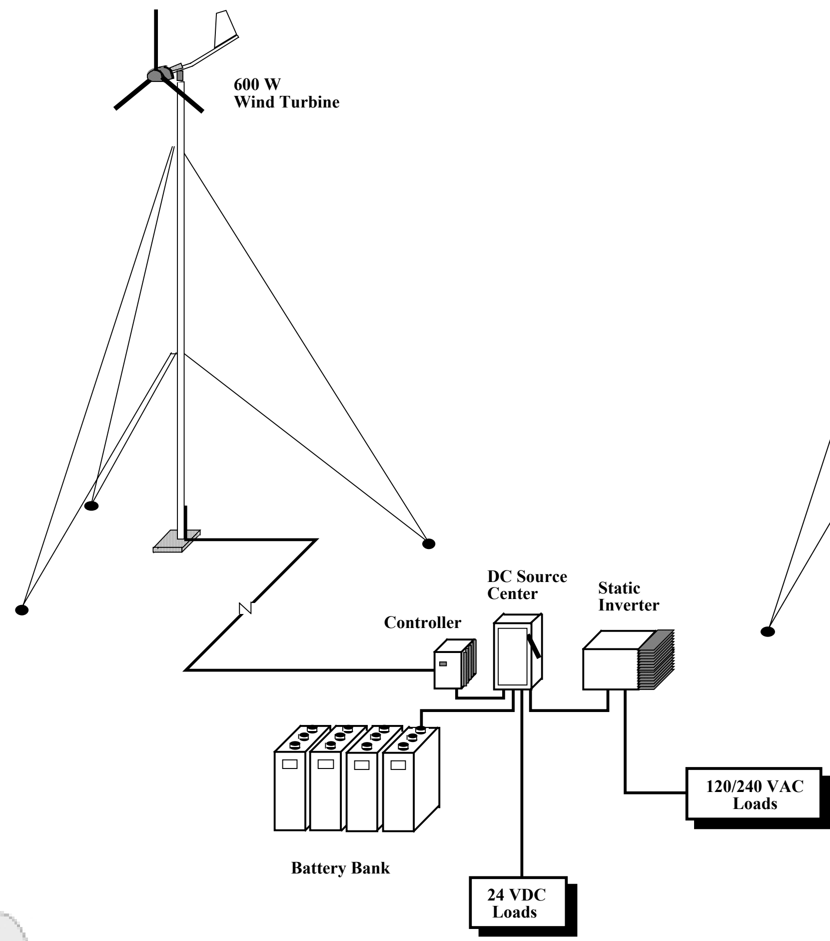
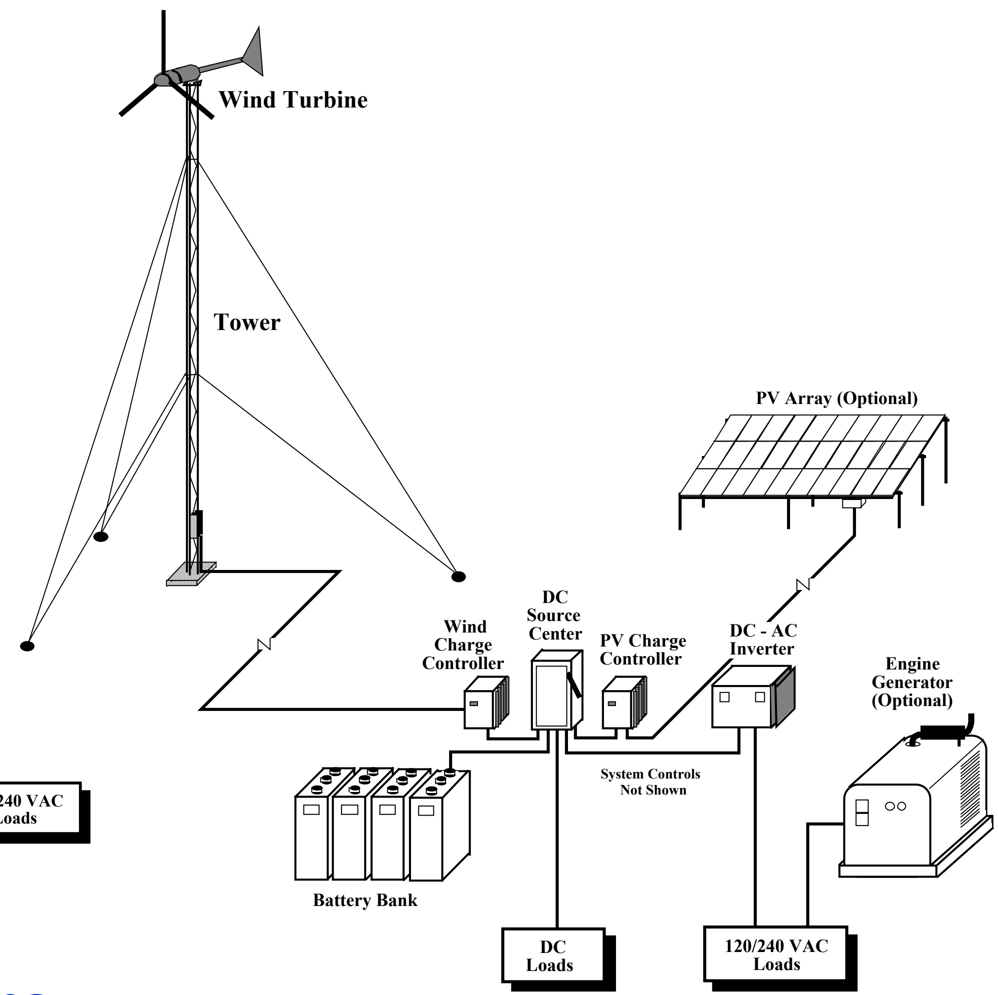
Hybrid Systems Design



Wind Home Systems



Hybrid Power System

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Steps in Design

1. **Use Best Available Information and Experience from Similar Installations to Establish Load (kWh/day) Requirements**
   - Load Estimates, Particularly in AC Systems, are Uncertain
   - Load Growth Often Considered at First, But Often Dropped
   - "Load Counting" Method is Common
2. **Convert AC Energy Requirements to DC Using Balance-of-System Efficiency, Such As:**
   - Battery Net Efficiency = 85%
   - Inverter Net Efficiency = 90%
   - Wiring Net Efficiency = 96%
   - "Controls" Net Efficiency = 90%

Total B.O.S. Efficiency = ~70%

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Steps in Design

3. **Use Best Available Information to Establish Monthly Average Wind Speed Estimates**
   – Usually as SWAG, So Safety Margins are Prudent
4. **Establish Site Conditions and Other Parameters Necessary for the Appropriate BWC Performance Model - Calculate Turbine Performance (DEO) for Each Month**
5. **Use Best Available Solar Resource Information to Establish Monthly Average Peak Sun Hours or kWh/m2/day**
   – First Approximation: PSH x Array Size = Daily Energy
6. **Calculate "Load Coverage" for each Month**
   – LC < 100% means back-up required
   – LC > 100% means dumped energy
   – Recommend Annual Average LC ~ 75% for hybrids with diesel back-up

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Steps in Design

7. **Iterate Calculations to Fit Project Design Goal**
   - Minimum Renewables Fraction
   - Typically, Renewables Fraction is Left up to Us to Propose
   - Minimum COE Usually NOT Scrutinized
8. **Choose Complete System Architecture - Single Line Schematic**
9. **Size Battery Bank**
   - Rule of Thumb: AH = 6 Times Rated Wind + PV Current
   - Higher AH for Telecom, Reduced Diesel Usage, Etc.
   - Lower AH for Larger Systems, Trade Winds, Etc.

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Steps in Design

10. **Size Inverter**
    - Rule of Thumb: Inverter kW = Total Renewables kW
    - Watch for High Surge Requirements (Induction Motors)
    - Bigger is Generally Better
11. **Size Back-up Generator**
    - Rule of Thumb: Generator kW = 1.25 x Total Renewables kW
    - Watch for Big Intermittent Loads (eg, commercial ice maker)
    - Too Big is Bad
12. **Complete Balance of Systems Design**
    - Tend to Favor Certain BOS Component Suppliers (eg, Trace inverters) … Design Standardization has Many Benefits
13. **Prepare Equipment & Services Budget**

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Load Counting

- Count and Define DC Loads
- Count and Define AC Loads
- Use Reference Lists for Typical Appliance Power Requirements
- Set BOS Efficiency Assumptions and Safety Margin to Calculate Equivalent Daily Energy at the DC Bus

HyCad

Design Model for DC Bus Type Hybrid Systems using Wind & Solar Power

Version 1.0

Village / Site:	Village
Country:	Mexico
Date:	11/30/00
Prepared By:	MB

Module 1: Loads Definition and Generation Requirements Worksheet

Direct Current (DC) Loads

Voltage (DC): 48
This Year: 2000
Design Year: 2000

Load No.	Description	How Many?	Power Req'd (W)	Hours Per Day	Daily Energy Now (DC kWh)	Load Growth Rate	Design Daily Energy (DC kWh)
1		0			0.0	0.0%	0.0
2					0.0	0.0%	0.0
3					0.0	0.0%	0.0
4					0.0	0.0%	0.0
5					0.0	0.0%	0.0
6					0.0	0.0%	0.0
7					0.0	0.0%	0.0
8					0.0	0.0%	0.0
9					0.0	0.0%	0.0
10					0.0	0.0%	0.0
11					0.0	0.0%	0.0
12					0.0	0.0%	0.0
13					0.0	0.0%	0.0
14					0.0	0.0%	0.0
15					0.0	0.0%	0.0
				Total (DC kWh):	0.0		0.0
				Total Amp-Hours:	0		0

Loads Summary

Daily Design DC Load (kWh):	0.0
Daily Design AC Load (kWh):	42.0

DC Energy Input Requirement

For DC Loads (DC kWh):	0.0
For AC Loads (DC kWh):	66.9
Total Daily DC kWh Req'd:	66.9

Alternating Current (AC) Loads

Voltage (AC): 230
Frequency: 50
This Year: 2000
Design Year: 2000

Load No.	Description	How Many?	Power Req'd (W)	Hours Per Day	Daily Energy Now (AC kWh)	Load Growth Rate	Design Daily Energy (AC kWh)
1	12 W CF Light	30	12	5	1.8	1.5%	1.8
2	16W CF Light	20	16	5	1.6	1.5%	1.6
3	60 W Light	10	60	5	3.0	1.5%	3.0
4	TV Set	10	120	6	7.2	1.5%	7.2
5	Radio	20	15	10	3.0	1.5%	3.0
6	Fans	20	75	8	12.0	1.5%	12.0
7	Refrigerator	4	140	24	13.4	1.5%	13.4
8					0.0	1.5%	0.0
9					0.0	1.5%	0.0
10					0.0	1.5%	0.0
11					0.0	1.5%	0.0
12					0.0	1.5%	0.0
13					0.0	1.5%	0.0
14					0.0	1.5%	0.0
15					0.0	1.5%	0.0
				Totals (AC kWh):	42.0		42.0

Balance of System (BOS) Efficiencies

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Load Counting

AC Loads

Load No.	Description	How Many?	Power Req'd (W)	Hours Per Day	Daily Energy Now (AC kWh)	Load Growth Rate	Design Daily Energy (AC kWh)
1	12 W CF Light	30	12	5	1.8	1.5%	1.8
2	16W CF Light	20	16	5	1.6	1.5%	1.6
3	60 W Light	10	60	5	3.0	1.5%	3.0
4	TV Set	10	120	6	7.2	1.5%	7.2
5	Radio	20	15	10	3.0	1.5%	3.0
6	Fans	20	75	8	12.0	1.5%	12.0
7	Refrigerator	4	140	24	13.4	1.5%	13.4
8					0.0	1.5%	0.0
9					0.0	1.5%	0.0
10					0.0	1.5%	0.0
11					0.0	1.5%	0.0
12					0.0	1.5%	0.0
13					0.0	1.5%	0.0
14					0.0	1.5%	0.0
15					0.0	1.5%	0.0
			Totals (AC kWh):		**42.0**		**42.0**

BOS Efficiencies

Balance of System (BOS) Efficiencies

Component / Aspect		DC	AC
Net Battery:	0.85	0.85	0.85
Inverter:	0.90	N.A.	0.90
Regulators:	0.98	0.98	0.98
Wiring:	0.98	0.98	0.98
Other:	1.00	1.00	1.00
Dumped Energy:	0.95	0.95	0.95
Safety Margin:	0.90	0.90	0.90
	Total:	**0.70**	**0.63**

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Load Counting

Resolving Loads to DC Energy Requirements

Loads Summary	
Daily Design DC Load (kWh):	0.0
Daily Design AC Load (kWh):	42.0

DC Energy Input Requirement	
For DC Loads (DC kWh):	0.0
For AC Loads (DC kWh):	66.9
Total Daily DC kWh Req'd:	66.9

The Renewable Energy Equipment needs to Average ~70 kWh DC / day to Satisfy the 42 kWh AC / day Total Load

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Appliance Loads

Appliance Type	Watts/Hour	Appliance Type	Watts/Hour
Coffee pot (10 cup)	1200	VCR -Off/Play	10/27
Coffee pot (4 cup)	650	CD Player	35
Toaster	1050	Stereo	10-300
Popcorn popper	250	Clock Radio	2
Blender	300	AM/FM car tape	8+
Microwave	600-1500	Satellite dish	30+
Waffle iron	1200	CB radio	5
Hot plate	1200	Electric clock	3
Frying pan	1200	Dishwasher	1200-1500
Sink waste disposal	450	Sewing machine	100
Washing machine - automatic - manual	 920 300+	Vacuum cleaner - upright - hand	 300-1100 100
Clothes dryer - electric - gas heated	 4000 300-400	Radio telephone - receive - transmit	 5 40-150
Iron	1000	Furnace blower	300-1000
Garage door opener	350	Ceiling fan	10-50
Table fan	10-250	Electric blanket	200
Blow dryer	1000+	Shaver	15
Waterpik	100	Electric mower	1500

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Appliance Loads

Appliance Type	Watts/Hour	Appliance Type	Watts/Hour
Computer		TV	
- laptop	20-50	- 25" color	150
- pc	80-220	- 19" TV or monitor	70-140
- printer-inkjet/laserjet/dotmatrix	50/600/180	- 12" b&w	20
Lights		Compact fluorescent incandescent equivalents	
- 100w incandescent	100		
- 25w compact fluor.	28	- 40watt equiv.	11
- 50w DC incandescent	50	- 60watt equiv.	16
- 40w DC halogen	40	- 75watt equiv.	20
- 20w DC compact fluor.	22	- 100watt equiv.	30
Hedge trimmer	450	Weed eater	500
1/4" drill	250+	9" disc sander	1200
1/2" drill	450+	3" belt sander	625-1000
1" drill	800	12" chain saw	1100-2400
7 1/4" circ. saw	1200+	14" band saw	1100-1800
8 1/4" circ. saw	1800	Typewriter	80-200
Air conditioner		Refrig/freezer	
- room	1000+	- 20cf (15 hours)	540
- central	2000-5000	- 16cf (13 hours)	475
Sunfrost (figure running 7hrs/day typically)		Freezer (figure running 10hrs/day typically)	
- 16cf DC	112	- 14cf ff (15)	440
- 12cf DC	70	- 14cf (14)	350

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Basic Hybrid Performance Model

Projected Daily Energy Output, By Month

Load: Daily DC kWh:	3.8
Sources: DC Equivalent kWh:	5
Wind Array Size, kW:	**1.5**
PV Array Size, kW:	**0.4**

Iterate

BOS Efficiencies	
Battery:	0.8
Inverter:	1
Wiring:	0.98
Misc.:	0.9
Total:	0.706

Month	1.5 kW Wind Daily Energy Output, kWh	1 kW PV Daily Energy Output, kWh	Wind Daily Energy Output, kWh	PV Daily Energy Output, kWh	Total Daily Energy Output, kWh	Load Coverage %
JAN	2.9	5.4	2.9	2.2	5.1	94%
FEB	3.5	5.5	3.5	2.2	5.7	106%
MAR	5.0	5.4	5.0	2.2	7.2	133%
APR	7.5	4.2	7.5	1.7	9.2	170%
MAY	9.1	3.3	9.1	1.3	10.4	193%
JUN	10.6	3.1	10.6	1.2	11.8	220%
JUL	10.2	3.1	10.2	1.2	11.4	212%
AUG	9.8	3.7	9.8	1.5	11.3	209%
SEP	8.6	4.5	8.6	1.8	10.4	193%
OCT	7.2	5.5	7.2	2.2	9.4	175%
NOV	5.6	5.6	5.6	2.2	7.8	146%
DEC	4.1	5.4	4.1	2.2	6.3	116%
Annual Ave.	7.0	4.6	7.0	1.8	8.8	164%

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Example Design Study

- Remote Home Electrification
- Pine Ridge Indian Reservation, Pine Ridge, South Dakota
- ~ 130 Homes without Electricity
- Planning a 10 System Pilot Project
- Nationally, 14.2% of Indian Homes are Without Electricity, Compared to 1.4% of all American Homes

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Loads

Alternating Current (AC) Loads

Voltage (AC):	**120**
Frequency:	**60**
This Year:	**1998**
Design Year:	**1998**

Load No.	Description	How Many?	Power Req'd (W)	Hours Per Day	Daily Energy Now (AC kWh)	Load Growth Rate	Design Daily Energy (AC kWh)
1	Refrigerator	1	90	5	0.5	1.5%	0.5
2	Microwave	1	1,000	1	1.0	1.5%	1.0
3	Lights	5	30	6	0.9	1.5%	0.9
4	Ceiling Fan	1	80	6	0.5	1.5%	0.5
5	TV	1	100	3	0.3	1.5%	0.3
6	Stereo	1	120	2	0.2	1.5%	0.2
7					0.0	1.5%	0.0
8					0.0	1.5%	0.0
9					0.0	1.5%	0.0
10					0.0	1.5%	0.0
11					0.0	1.5%	0.0
12					0.0	1.5%	0.0
13					0.0	1.5%	0.0
14					0.0	1.5%	0.0
15					0.0	1.5%	0.0
			Totals (AC kWh):		**3.4**		**3.4**

BERGEY WINDPOWER

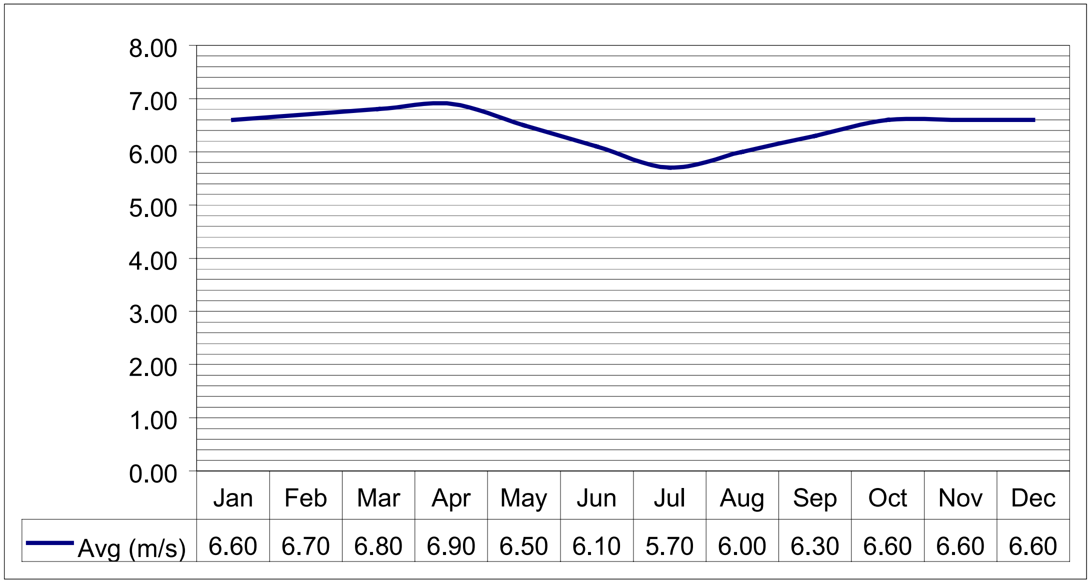
Wind Resources

Annual Wind Data

Prepared For:	Bergey WindPower Company
Site Location:	Pine Ridge Indian Reservation, SD
Data Source:	US DOE Wind Energy Resource Atlas
Date:	30/11/2000
Data Collection Location:	Rapid City, SD
Data Collection Height (m):	19.2

Season	Average windspeed
Winter	6.6
Spring	6.9
Summer	5.7
Fall	6.6
Annual	6.45

Month	Average windspeed
Jan	6.60
Feb	6.70
Mar	6.80
Apr	6.90
May	6.50
Jun	6.10
Jul	5.70
Aug	6.00
Sep	6.30
Oct	6.60
Nov	6.60
Dec	6.60
avg	6.45



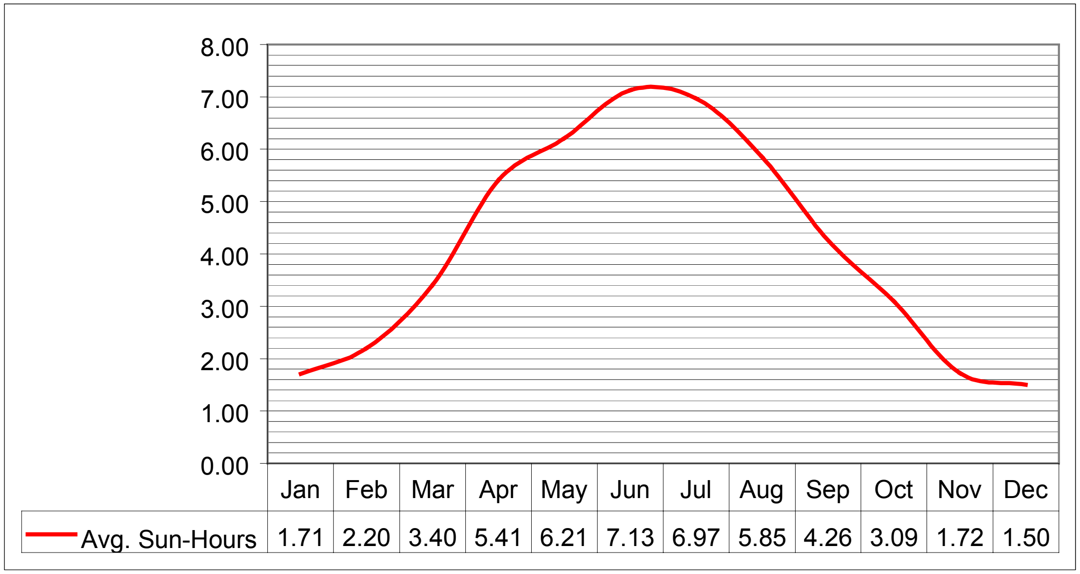
BERGEY WINDPOWER

Solar Resources

Annual Solar Data

Prepared For:	Bergey WindPower Company
Site Location:	Pine Ridge Indian Reservation, SD
Data Source:	NASA Satellite Data
Date:	30/11/2000
Data Collection Location:	Cell 5601, 42.50 to 45.00 N, 100.38 to 103.85 W

Month	Average Sun Hours
Jan	1.71
Feb	2.20
Mar	3.40
Apr	5.41
May	6.21
Jun	7.13
Jul	6.97
Aug	5.85
Sep	4.26
Oct	3.09
Nov	1.72
Dec	1.50
avg	4.12



BERGEY WINDPOWER

WindCAD

WindCad Turbine Performance Model

BWC XL.1 Battery Charging Version

MS Excel, V.97 PC

Prepared For:	**Bergey WindPower Co.**
Site Location:	**Pine Ridge, SD, USA**
Data Source:	**US-DOE Wind Energy Atlas**
Date:	**11/30/00**

1 kW

Inputs:

Ave. Wind (m/s) =	6.45
Weibull K =	2
Site Altitude (m) =	981
Wind Shear Exp. =	0.220
Anem. Height (m) =	19.2
Tower Height (m) =	10
Turbulence Factor =	5.0%
Perf. Safety Margin =	5.0%

Results:

Hub Average Wind Speed (m/s) =	5.59
Air Density Factor =	-9.0%
Average Output Power (W) =	244
Daily Energy Output (kWh) =	**5.6**
Annual Energy Output (kWh) =	2,028
Monthly Energy Output =	169
Percent Operating Time =	85.5%

Weibull Performance Calculations

Wind Speed Bin (m/s)	Power (W)	Wind Probability (f)	Net W @ V
1	0	4.95%	0.00
2	2	9.17%	0.16
3	19	12.11%	2.30
4	52	13.52%	7.01
5	108	13.45%	14.54
6	199	12.21%	24.28
7	324	10.25%	33.22
8	458	8.00%	36.67
9	605	5.85%	35.40
10	761	4.01%	30.53
11	925	2.59%	23.97
12	1,037	1.58%	16.36
13	1,063	0.91%	9.64
14	1,037	0.49%	5.10
15	994	0.25%	2.51
16	947	0.12%	1.16
17	899	0.06%	0.51
18	856	0.02%	0.21
19	813	0.01%	0.08
20	769	0.00%	0.03
Totals:		99.57%	243.69

Weibull Calculations:
Wind speed probability is calculated as a Weibull curve defined by the average wind speed and a shape factor, K. To facilitate piece-wise integration, the wind speed range is broken down into "bins" of 1 m/s in width (Column 1). For each wind speed bin, instantaneous wind turbine power (W, Column 2)) is multiplied by the Weibull wind speed probability (f, Column 3). This cross product (Net W, Column 4) is the contribution to average turbine power output contributed by wind speeds in that bin. The sum of these contributions is the average power output of the turbine on a continuous, 24 hour, basis.
Best results are achieved using annual or monthly average wind speeds. Use of daily or hourly average speeds is not

BERGEY WINDPOWER

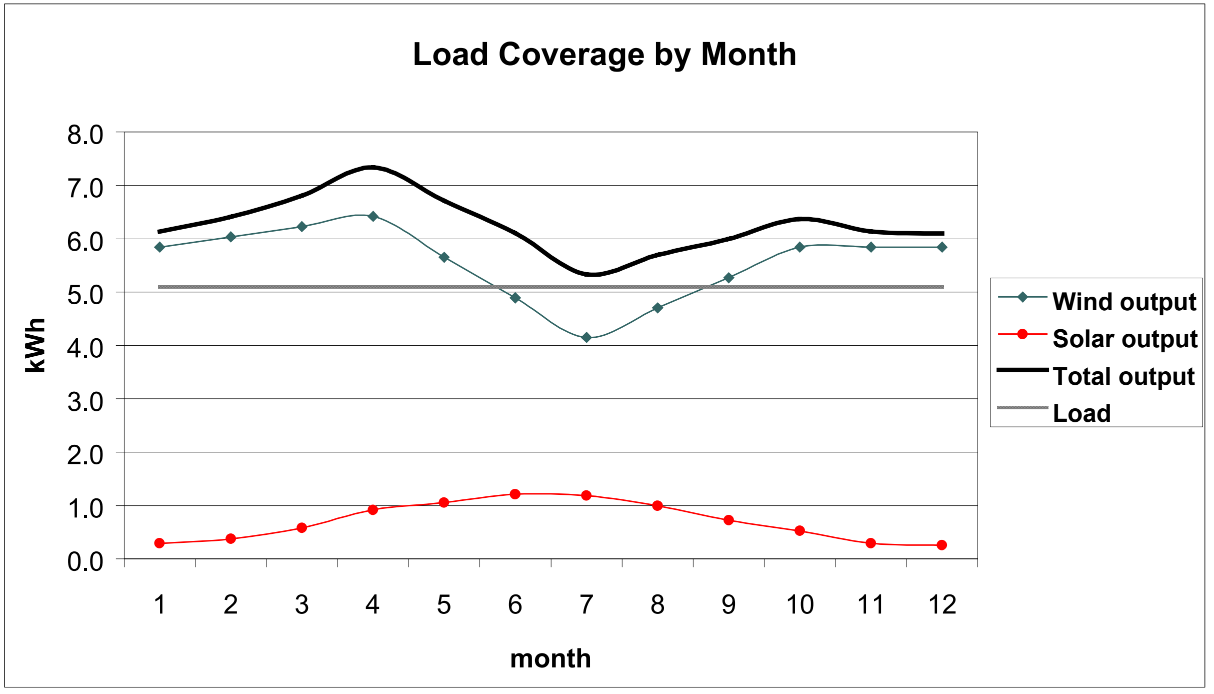
Hybrid Model

Projected Daily Energy Output, By Month
Pine Ridge Indian Reservation, SD

Load: Daily DC kWh:	3.4
Sources: DC Equivalent kWh:	5.10
Wind Array Size, kW:	**1**
PV Array Size, kW:	**0.2**

BOS Efficiencies	
Battery:	0.85
Inverter:	0.9
Wiring:	0.98
Misc.:	0.89
Total:	0.667

Month	1.0 kW Wind Daily Energy Output, kWh	1 kW PV Daily Energy Output, kWh	Wind Daily Energy Output, kWh	PV Daily Energy Output, kWh	Total Daily Energy Output, kWh	Avg. Daily Load	Load Coverage %
JAN	5.8	1.5	5.8	0.3	6.1	5.10	120%
FEB	6.0	1.9	6.0	0.4	6.4	5.10	126%
MAR	6.2	2.9	6.2	0.6	6.8	5.10	134%
APR	6.4	4.6	6.4	0.9	7.3	5.10	144%
MAY	5.7	5.3	5.7	1.1	6.7	5.10	132%
JUN	4.9	6.1	4.9	1.2	6.1	5.10	120%
JUL	4.1	5.9	4.1	1.2	5.3	5.10	105%
AUG	4.7	5.0	4.7	1.0	5.7	5.10	112%
SEP	5.3	3.6	5.3	0.7	6.0	5.10	118%
OCT	5.8	2.6	5.8	0.5	6.4	5.10	125%
NOV	5.8	1.5	5.8	0.3	6.1	5.10	120%
DEC	5.8	1.3	5.8	0.3	6.1	5.10	120%
Annual Ave.	5.6	4.1	5.6	0.7	6.3	5.10	123%



BERGEY WINDPOWER

Proposed Systems

10 Systems:

- 1 kW wind turbine, with 9 m guyed tower ($1,985)
- 0.2 kW solar array, mounted to wind turbine tower ($1,460)
- 10.6 kWh battery bank ($760)
- 0.5 kW inverter, with battery-charging ($495)
- 0.9 kW gas-powered back-up generator ($750)
- Wiring kit ($360)
- 9.5 ft3 high-efficiency refrigerator ($400)
- (5) high-efficiency CF lights ($125)

Equipment Total: $6,335 each

<u>Add:</u>

Shipping ($360)

Installation ($1,000)

Training ($250)

Total: $1,550

Total Installed Cost: $7,885 per system

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